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Review Article

Single-Port Laparoscopic Cholecystectomy: Current Evidence, Technical Challenges, and Clinical Outcomes

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Abstract

Background: Single-port laparoscopic cholecystectomy (SPLC) has emerged as an innovative advancement in minimally invasive surgery aimed at further reducing surgical trauma and improving cosmetic outcomes compared with conventional multi-port laparoscopic cholecystectomy. The technique involves performing gallbladder removal through a single umbilical incision, offering the potential benefits of reduced scarring and improved patient satisfaction.
Methods: A narrative review of the literature was conducted using electronic databases including PubMed, Scopus, and Google Scholar. Relevant studies published were identified using keywords such as "single-port cholecystectomy," "single-incision laparoscopic surgery," "SPLC," and "laparoendoscopic single-site surgery." Randomized controlled trials, observational studies, systematic reviews, and meta-analyses evaluating operative outcomes and clinical safety were included.
Results: Available evidence suggests that SPLC provides superior cosmetic outcomes and high patient satisfaction while maintaining comparable complication rates to conventional laparoscopic cholecystectomy. Although operative time may initially be longer due to technical challenges such as instrument crowding and limited triangulation, outcomes improve with surgical experience. Hospital stay, postoperative pain, and overall recovery are generally similar between the two approaches.
Conclusion: Single-port laparoscopic cholecystectomy is a feasible and safe alternative to conventional laparoscopic cholecystectomy in appropriately selected patients. Continued technological advancements and further high-quality studies will help define its future role in minimally invasive surgery.

Keywords: Single-port laparoscopic cholecystectomy, single-incision laparoscopic surgery, minimally invasive surgery, gallbladder surgery, laparoendoscopic single-site surgery, cholecystectomy outcomes

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Introduction

Gallstone disease is one of the most common gastrointestinal disorders worldwide and represents a significant cause of morbidity requiring surgical intervention.[1,2] Cholecystectomy remains the definitive treatment for symptomatic gallbladder disease, including cholelithiasis, cholecystitis, and gallstone-related complications.[3] Since the first successful open cholecystectomy performed by Carl Langenbuch in 1882, surgical management of gallbladder disease has undergone remarkable evolution with the aim of reducing surgical trauma and improving postoperative recovery.[4]
The introduction of laparoscopic cholecystectomy in the late 1980s marked a revolutionary milestone in general surgery and rapidly became the gold standard for the treatment of symptomatic gallstone disease.[5] Compared with the conventional open approach, laparoscopic cholecystectomy offers several advantages, including reduced postoperative pain, shorter hospital stay, faster return to daily activities, and improved cosmetic outcomes.[6] Traditionally, the laparoscopic technique utilizes three to four abdominal ports to achieve adequate visualization, triangulation, and instrument manipulation during the procedure.[7]
In recent years, continued efforts to further minimize surgical invasiveness have led to the development of laparoendoscopic single-site surgery (LESS), which aims to perform procedures through a single incision, most commonly at the umbilicus.[8,9] Single-port laparoscopic cholecystectomy (SPLC) has emerged as one of the most widely adopted applications of this approach.[10] By reducing the number of incisions to a single access point, SPLC seeks to improve cosmetic outcomes and potentially decrease postoperative discomfort while maintaining the safety and effectiveness of conventional laparoscopic techniques.

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Despite these potential advantages, SPLC presents several technical challenges, including loss of instrument triangulation, instrument crowding, and a potentially longer operative time.[11] These factors have generated ongoing debate regarding its clinical benefits, safety profile, and widespread adoption in routine surgical practice. Over the past decade, numerous studies, including randomized controlled trials and meta-analyses, have attempted to evaluate the feasibility, outcomes, and limitations of this technique compared with conventional multi-port laparoscopic cholecystectomy.

Therefore, this review aims to provide a comprehensive overview of single-port laparoscopic cholecystectomy, including its historical evolution, surgical techniques, clinical outcomes, advantages, limitations, and future directions in minimally invasive gallbladder surgery.

Methods

This review was conducted as a narrative literature review to summarize the current evidence regarding single-port laparoscopic cholecystectomy (SPLC), including its evolution, operative techniques, clinical outcomes, advantages, and limitations. A comprehensive search of electronic databases including **PubMed, Scopus, and Google Scholar** was performed to identify relevant studies published in the field of minimally invasive gallbladder surgery.

The literature search included open access articles published, corresponding to the period during which single-port laparoscopic techniques began to gain wider clinical adoption. The search strategy utilized combinations of the following keywords and Medical Subject Headings (MeSH): *"single-port cholecystectomy," "single-incision laparoscopic surgery," "SPLC," "laparoendoscopic single-site surgery (LESS)," "single-incision laparoscopic cholecystectomy,"* and *"minimally invasive gallbladder surgery."* Boolean operators such as **AND** and **OR** were applied to refine the search results.

Eligible studies included **randomized controlled trials, prospective and retrospective observational studies, systematic reviews, meta-analyses, and relevant review articles** that evaluated the technical aspects, perioperative outcomes, and clinical effectiveness of SPLC. Studies comparing SPLC with conventional multi-port laparoscopic cholecystectomy were also considered to assess differences in operative time, postoperative pain, complications, cosmetic outcomes, and patient recovery.

Articles published in **English** and involving **human subjects** were included. Studies focusing on unrelated surgical procedures, duplicate publications, conference abstracts lacking full data, and studies with insufficient methodological details were excluded from the review. Additional relevant references were identified through **manual screening of reference lists** from selected articles to ensure comprehensive coverage of key studies in the field.

The collected literature was analyzed qualitatively, and key findings were synthesized to provide an overview of the current evidence regarding the feasibility, safety, and clinical outcomes of single-port laparoscopic cholecystectomy.

Evolution and Historical Development of Single-Port Cholecystectomy

Cholecystectomy has undergone significant transformation over the past century as surgical practice has progressively moved toward less invasive techniques.[12] The first successful open cholecystectomy was performed by **Carl Langenbuch in 1882**, establishing surgical removal of the gallbladder as the definitive treatment for symptomatic gallstone disease.[4] For more than a century, the open approach remained the standard until the introduction of laparoscopic surgery fundamentally changed the landscape of general surgery.[13]

The late 1980s witnessed the advent of **laparoscopic cholecystectomy**, which rapidly became the gold standard for the management of gallbladder disease.[5] Early pioneering work by surgeons such as **Erich Mühe**, who performed one of the first laparoscopic cholecystectomies in 1985, demonstrated that minimally invasive techniques could achieve outcomes comparable to open surgery while offering significant advantages in terms of postoperative recovery, reduced pain, and shorter hospital stays.[14] Over time, the conventional multi-port laparoscopic approach, typically utilizing three to four ports, became widely adopted due to its safety, reproducibility, and effectiveness.

As laparoscopic surgery continued to evolve, surgeons began exploring ways to further reduce surgical trauma and improve cosmetic outcomes. This pursuit led to the development of **laparoendoscopic single-site surgery (LESS)**, a minimally invasive technique designed to perform abdominal procedures through a single incision, usually located at the umbilicus.[8,15] By utilizing a single access point, the procedure aims to minimize visible scarring and potentially reduce postoperative discomfort while maintaining adequate visualization and operative safety.

The first reported cases of **single-incision laparoscopic cholecystectomy** appeared in the late 1990s and early 2000s, with Navarra and colleagues describing one of the earliest techniques involving transumbilical access using multiple instruments through a single incision.[16] Subsequent technological advances, including the introduction of specialized single-port access devices, articulating laparoscopic instruments, and flexible endoscopes, facilitated the wider adoption of this technique.

During the late 2000s and early 2010s, single-port laparoscopic cholecystectomy gained considerable attention as surgeons sought to evaluate its feasibility and potential advantages over conventional multi-port laparoscopy.[17] While the technique demonstrated promising cosmetic benefits, concerns regarding technical difficulty, loss of instrument triangulation, and longer operative times were also highlighted.

More recently, ongoing technological developments, such as improved articulating instruments and the introduction of **robotic single-port platforms** have aimed to address some of the technical limitations associated with conventional single-port laparoscopic surgery.[18,19] These advancements continue to expand the possibilities of minimally invasive surgical approaches and may play an important role in shaping the future of gallbladder surgery.

Surgical Technique of Single-Port Laparoscopic Cholecystectomy

Single-port laparoscopic cholecystectomy (SPLC) is typically performed through a single transumbilical incision that allows the insertion of multiple instruments through a single access platform.[20] The technique aims to replicate the principles of conventional laparoscopic cholecystectomy while minimizing the number of abdominal incisions. Although several technical variations exist, the fundamental operative steps remain similar to those of standard laparoscopic procedures.

Patient Positioning and Preparation: The patient is usually placed in the **supine position** under general anesthesia. After induction, the operating table is adjusted to a **reverse Trendelenburg position with slight left tilt**, which facilitates gravitational retraction of the abdominal contents and improves visualization of the gallbladder and hepatobiliary structures. Standard antiseptic preparation and sterile draping of the abdomen are performed prior to incision.[21]

Port Placement and Access: A **2–3 cm vertical or curved transumbilical incision** is commonly used to access the abdominal cavity. Through this incision, a specialized single-port device or multiple trocars placed through a single fascial opening may be inserted. Several commercially available access platforms, such as SILS ports or multi-channel ports, allow the introduction of a laparoscope along with working instruments through the same incision. Carbon dioxide pneumoperitoneum is established, typically

maintaining an intra-abdominal pressure of **12–15 mmHg**. A laparoscope, often a **30-degree angled scope**, is introduced to provide adequate visualization of the operative field.[22]

Instrumentation: Due to the limited access through a single incision, **articulating or curved laparoscopic instruments** are frequently used to facilitate dissection and improve maneuverability. These specialized instruments help overcome the challenge of instrument crowding and allow surgeons to recreate a degree of triangulation during the procedure. In some cases, a transabdominal suture or retraction device may be used to assist with gallbladder retraction.[23]

Operative Steps: After gaining access to the abdominal cavity, the gallbladder is retracted superiorly to expose **Calot's triangle**. Careful dissection is performed to clearly identify the **cystic duct and cystic artery**, ensuring achievement of the **critical view of safety**, which is essential for preventing bile duct injury. Once the anatomy is adequately visualized, the cystic duct and cystic artery are secured using laparoscopic clips or energy devices and subsequently divided. The gallbladder is then dissected from the gallbladder bed using electrocautery or other energy sources. Hemostasis is ensured throughout the dissection process. Following complete mobilization, the gallbladder is retrieved through the umbilical incision, often using a specimen retrieval bag to prevent contamination. After confirming hemostasis and the absence of bile leakage, the pneumoperitoneum is released and the fascial and skin incisions are closed in layers.[24]

Technical Variations: Several modifications of SPLC have been described in the literature. Some surgeons utilize **additional retraction sutures** placed through the abdominal wall to improve exposure, while others may introduce an auxiliary mini-port in difficult cases to facilitate safer dissection. Advances in **robotic-assisted single-port surgery** have also been explored to improve instrument dexterity and overcome ergonomic limitations associated with conventional SPLC.

Advantages of Single-Port Laparoscopic Cholecystectomy

Single-port laparoscopic cholecystectomy (SPLC) has emerged as an evolution of minimally invasive surgery aimed at further reducing surgical trauma while maintaining the safety and effectiveness of conventional laparoscopic techniques. Several potential advantages have been reported in the literature, particularly in relation to cosmetic outcomes, postoperative recovery, and patient satisfaction.

Improved Cosmetic Outcomes: One of the most widely recognized benefits of SPLC is the **superior cosmetic result**. Since the procedure is performed through a single incision, typically concealed within the umbilicus, the resulting scar is often minimal or virtually invisible. This characteristic is particularly appealing to younger patients and individuals who place significant value on aesthetic outcomes. Several clinical studies have demonstrated higher patient satisfaction scores regarding postoperative scar appearance when compared with conventional multi-port laparoscopic cholecystectomy.[25]

Reduced Surgical Trauma: By limiting the number of abdominal incisions to a single access point, SPLC potentially reduces **overall abdominal wall trauma**. Conventional laparoscopic cholecystectomy typically requires three or four trocar sites, each contributing to tissue injury and postoperative discomfort. The single-incision approach minimizes these entry points, which may theoretically reduce tissue damage and associated inflammatory responses.[26]

Potential Reduction in Postoperative Pain: Some studies have suggested that SPLC may be associated with **reduced postoperative pain**, particularly during the early postoperative period. The reduction in the number of trocar sites may contribute to decreased somatic pain originating from the abdominal wall. However, findings in the literature remain mixed, and several randomized trials have reported comparable pain scores between SPLC and conventional laparoscopic approaches.[27]

Faster Recovery and Early Mobilization: Minimally invasive techniques are generally associated with **shorter recovery times and earlier return to normal activities**, and SPLC follows this trend. Patients undergoing single-port surgery may experience earlier mobilization and shorter hospital stays, although many of these benefits overlap with those already achieved by standard laparoscopic cholecystectomy.[28]

Enhanced Patient Satisfaction: Patient-centered outcomes have gained increasing importance in modern surgical practice. The combination of improved cosmetic results, minimal scarring, and the perception of a less invasive procedure often leads to **high patient satisfaction** following SPLC. Studies assessing patient-reported outcomes frequently highlight cosmetic appearance as a key factor influencing patient preference for single-incision procedures.[29]

Table 1. Comparison Between Single-Port and Conventional Laparoscopic Cholecystectomy

Parameter	Single-Port Laparoscopic Cholecystectomy (SPLC)	Conventional Laparoscopic Cholecystectomy
Number of incisions	Single umbilical incision	3–4 abdominal ports
Cosmetic outcome	Superior cosmetic appearance	Small but visible scars
Operative time	Often longer due to technical complexity	Generally shorter
Instrument triangulation	Limited	Well established
Postoperative pain	Comparable or slightly reduced	Standard postoperative pain
Recovery time	Similar or slightly faster	Rapid recovery
Complication rates	Comparable in experienced hands	Well established safety

Limitations and Technical Challenges of Single-Port Laparoscopic Cholecystectomy

Despite the potential advantages associated with single-port laparoscopic cholecystectomy (SPLC), the technique presents several technical and procedural challenges that have limited its universal adoption. Many of these challenges arise from the constraints imposed by operating through a single access point, which can affect instrument maneuverability, visualization, and overall surgical ergonomics.

Loss of Instrument Triangulation: One of the most significant limitations of SPLC is the **loss of traditional instrument triangulation**. In conventional laparoscopic cholecystectomy, multiple ports allow instruments to approach the operative field from different angles, facilitating precise dissection and retraction. In contrast, SPLC requires instruments to be inserted through the same incision, resulting in parallel instrument alignment. This arrangement can make delicate dissection, particularly within **Calot's triangle**, more technically demanding.[23]

Instrument Crowding and External Clashing: Because the laparoscope and working instruments share a single entry point, **instrument crowding** within the operative field is a common challenge. Additionally, the handles of instruments outside the abdominal cavity may collide with each other, often referred to as the "sword fighting" phenomenon. These ergonomic limitations can reduce surgical efficiency and contribute to increased operative time, particularly during the early stages of a surgeon's experience with the technique.[23]

Prolonged Operative Time: Several studies have reported that SPLC may be associated with **longer operative times** compared with conventional multi-port laparoscopic cholecystectomy. The increased technical complexity, limited working angles, and need for careful instrument manipulation can slow the dissection process. However, operative times generally decrease as surgeons gain experience and overcome the learning curve associated with the procedure.[27,28]

Steep Learning Curve: SPLC requires advanced laparoscopic skills and familiarity with specialized instrumentation. Surgeons must adapt to altered ergonomics, limited triangulation, and unconventional hand movements. As a result, the procedure is often considered to have a **steeper learning curve** compared with traditional laparoscopic cholecystectomy. Several studies suggest that surgeons may require approximately **20–40 procedures** to achieve proficiency and consistent operative efficiency.[30]

Risk of Incisional Complications: Since SPLC involves a slightly larger umbilical incision to accommodate the single-port device, there is a theoretical concern regarding an increased risk of **umbilical hernia or wound complications**. Although current evidence suggests that the overall incidence remains low, careful closure of the fascial defect is essential to minimize postoperative complications.

Limited Applicability in Complex Cases: SPLC may not be suitable for all patients. Cases involving **severe acute cholecystitis, dense adhesions, morbid obesity, or previous upper abdominal surgery** can increase procedural difficulty and may necessitate conversion to multi-port laparoscopy or open surgery. Therefore, appropriate patient selection remains an important factor in ensuring procedural safety.

Table 2. Summary of Reported Clinical Outcomes in SPLC Studies

Outcome Parameter	Findings Reported in Literature
Operative time	Often longer during early experience
Postoperative pain	Comparable or slightly reduced
Hospital stay	Similar to conventional laparoscopy
Complication rates	Generally comparable
Conversion rates	Low but slightly higher during learning curve
Cosmetic satisfaction	Significantly higher in SPLC

Patient Selection for Single-Port Laparoscopic Cholecystectomy

Appropriate patient selection is a critical factor in ensuring the safety and success of single-port laparoscopic cholecystectomy (SPLC). Although the procedure has demonstrated favorable outcomes in many studies, it is generally considered most suitable for carefully selected patients, particularly during the early stages of a surgeon's experience with the technique. Proper selection helps minimize intraoperative difficulties and reduces the likelihood of complications or conversion to additional ports.

Ideal Candidates: Patients with **uncomplicated gallbladder disease** are generally considered the most appropriate candidates for SPLC. These typically include individuals with symptomatic cholelithiasis, biliary colic, or chronic cholecystitis without significant inflammatory changes. In such cases, the anatomy is usually well defined, allowing safe identification of critical structures during dissection.[21]

Patients with **normal or moderately elevated body mass index (BMI)** are often preferred candidates, particularly during the initial adoption phase of the technique. Lower BMI facilitates easier visualization and manipulation of instruments through the single access port. Additionally, patients without prior abdominal surgery, especially in the upper abdomen, are ideal, as this reduces the likelihood of adhesions that may complicate the procedure.

Relative Contraindications: Certain clinical situations may increase the technical difficulty of SPLC and therefore require careful consideration. Patients presenting with **acute severe cholecystitis, empyema of the gallbladder, or significant inflammatory changes** may pose challenges in achieving safe dissection within Calot's triangle. Dense adhesions, distorted anatomy, and increased vascularity in these cases can increase the risk of complications. Similarly, patients with **morbid obesity, previous upper abdominal surgeries, or suspected biliary tract anomalies** may not be ideal candidates for a single-port approach. In such cases, conventional multi-port laparoscopic cholecystectomy may provide improved instrument triangulation and better operative exposure.

Surgeon Experience and Institutional Factors: Beyond patient-related factors, **surgeon expertise plays a crucial role in determining suitability for SPLC**. Surgeons with extensive experience in conventional laparoscopic cholecystectomy are better positioned to adapt to the technical challenges associated with the single-port approach. Many experts recommend beginning with carefully selected low-risk cases during the early learning phase before attempting more complex procedures. Institutional factors, including the availability of specialized equipment and trained surgical teams, may also influence the feasibility of performing SPLC. As experience with the technique increases and technological advancements continue to evolve, the range of suitable patients may expand accordingly.

Future Directions and Technological Advances

Continuous advancements in minimally invasive surgical technology are expected to play a crucial role in overcoming the current limitations associated with single-port laparoscopic cholecystectomy. One of the most promising developments in this field is the introduction of **robotic-assisted single-port surgical systems**, which provide enhanced instrument articulation, improved dexterity, and superior visualization compared with conventional laparoscopic instruments.

Robotic platforms designed specifically for single-port surgery allow surgeons to operate with increased precision while minimizing the ergonomic challenges commonly encountered in traditional SPLC. These systems may help address issues such as instrument clashing and restricted movement within the confined operative space.

In addition to robotic innovations, the development of **advanced articulating laparoscopic instruments, flexible endoscopes, and improved access platforms** continues to expand the possibilities of single-incision surgery. Ongoing research is also exploring the integration of **natural orifice transluminal endoscopic surgery (NOTES)** techniques, which aim to perform abdominal procedures through natural body openings, potentially eliminating visible scars altogether.

Future research should focus on **large-scale randomized controlled trials and long-term outcome studies** to better define the role of SPLC in routine surgical practice. Further technological improvements and growing surgical expertise may ultimately enhance the safety, efficiency, and accessibility of single-port procedures.

Conclusion

Single-port laparoscopic cholecystectomy represents an important advancement in the field of minimally invasive surgery. By reducing the number of abdominal incisions to a single access point, the technique offers improved cosmetic outcomes and high levels of patient satisfaction while maintaining the fundamental principles of laparoscopic cholecystectomy.

Current evidence indicates that SPLC is a **feasible and safe alternative to conventional multi-port laparoscopic cholecystectomy** in carefully selected patients when performed by experienced surgeons. Although the procedure is associated with certain technical challenges, such as loss of triangulation, instrument crowding, and a steeper learning curve, these limitations can often be overcome with increasing surgical experience and the use of specialized instrumentation.

While operative times may initially be longer, many studies have demonstrated comparable complication rates, hospital stay, and overall clinical outcomes between SPLC and conventional laparoscopic techniques. As technological advancements continue to improve instrument design and robotic surgical platforms become more widely available, the role of single-port surgery is likely to expand further.

In conclusion, SPLC represents a promising approach in the ongoing evolution of minimally invasive gallbladder surgery. Continued research, technological innovation, and surgical training will be essential to fully establish its place in modern surgical practice.

Declarations

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